PATENT SPECIFICATION

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(54) ROLLER BEARINGS

(71) We, THE GARRETT CORPORATION, a Corporation organised under the laws of the State of California, United States of America, of 9851—9951 Sepulveda Boulevard, P.O. Box 92248, Los Angeles, California 90009, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to roller bearings.

A roller bearing normally includes inner and outer members each having a raceway, and a plurality of bearing rollers arranged between the raceways. The rollers are normally separated by a cage, and their axial position is controlled by at least one end flange formed beside one of the raceways. A common problem is that wear occurs at the engagement between the roller end faces and the end flange or flanges. This wear is often responsible for limiting the life of the bearing, since it leads to loss of control of the rollers, loading and consequent fatigue failure of the cage, increased skidding of the rollers on the raceways, and subsequent complete failure of the bearing. These problems are particularly prevalent in high speed bearings such as are used in gas turbine engines.

In many cases, roller end wear occurs when the rollers become skewed; the shapes of the engaging surfaces of the end flange and the roller ends are normally such that this skewing results in metal-to-metal contact between the flange and the roller ends. The occurrence of moments tending to produce such skewing is dependent on slight dimensional variations, such as blend radii, raceway taper, roller taper, roller crowning variations, and off-square roller ends, and because these variations are unpredictable, the bearing life will be similarly unpredictable.

According to one aspect of the present invention, a roller bearing comprises inner and outer members each having a circular raceway, and a plurality of bearing rollers arranged between the raceways, at least one of the inner and outer members having at least one circumferential flange beside its raceway, which flange has a convex surface arranged to engage an end face of each bearing roller to restrain the bearing rollers against axial movement, the convex surface of the flange diverging, in the direction towards the part of the flange which lies furthest from the raceway of the said one member, hereinafter referred to as the crest of the flange, from a plane perpendicular to the axis of an adjacent bearing roller, the said divergence extending from the said raceway to the crest of the flange, and the convex surface of the flange and the end faces of the bearing rollers being so shaped that, even with a bearing roller in its most extreme skewed position, the point of closest engagement between the flange and the bearing roller is spaced from the crest of the flange, with that part of the space between the flange and the bearing roller which also lies between the crest of the flange and the said point of closest engagement being wedge-shaped. The presence of this wedge-shaped space helps to ensure that a hydrodynamic lubricant film is maintained between the end flange and the roller end, so that roller end wear is minimised.

According to another aspect of the invention, a roller-bearing includes a plurality of bearing rollers rolling between inner and outer raceways, with the end faces of the rollers in engagement with a convex flange formed beside one of the raceways, and the flange diverges, in the direction away from the said one raceway, from a plane perpendicular to the axis of an adjacent bearing roller, with the said divergence extending along the whole height of the flange, and the points of closest engagement between the flange and the bearing rollers are spaced from the crest of the flange,

resulting in a wedge-shaped space being formed between the flange and each bearing roller, along the part of the height of the flange lying between the crest of the flange and the said point of closest engagement, and the bearing being so arranged that, when the inner and outer raceways are rotated relative to one another, the velocity of each bearing roller relative to the flange at the respective said point of closest engagement includes a component directed from crest to base of the flange, which component produces a hydrodynamic lubricant film between the flange and the bearing roller.

The invention also provides, according to a third aspect, a roller bearing assembly having an inner race, an outer race, and a plurality of cylindrical rollers each having opposed end faces and a cylindrical surface in rolling engagement with the inner and outer races; a pair of radially extending flanges on one of the races adjacent the opposed end faces of the rollers, the said flanges presenting convexly curved surfaces engageable with the said end faces, which curved surfaces diverge, in the direction away from the part of the said one race which joins the said two flanges, from a plane perpendicular to the axis of an adjacent roller, with the said divergence extending along the whole height of the flange.

The invention may be carried into practice in various ways, but two specific embodiments will now be described by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a fragmentary sectional view of a roller bearing embodying the present invention;

Figure 2 is an enlarged sectional view of the end flange portion of the inner raceway of the roller bearing, corresponding to the area within the circle 2 in Figure 1;

Figure 3 is a further enlarged, fragmentary view of the corner of one of the rollers of the bearing;

Figure 4 is a top plan view of a roller and part of the inner raceway;

Figure 5 is an end view of the roller and part of the inner race;

Figure 6 is a view similar to Figure 2 but showing the roller in its typical skewed disposition;

Figure 7 is a view similar to Figure 6 but showing a known form of roller bearing;

Figure 8 is an enlarged, fragmentary, sectional view of the end flange area of another roller bearing embodying the present invention;

Figure 9 is an enlarged, partial plan view of a roller and part of the inner race of the bearing shown in Figure 8;

Figure 10 is an end view of the roller and part of the inner race;

Figure 11 is a view similar to Figure 8 but showing the roller in its typical, skewed disposition; and

Figure 12 is a view similar to Figure 11 but showing a known form of roller bearing.

Referring now to the drawings, Figures 1 to 6 show a roller bearing 13 which includes an inner bearing race 14, an outer race 15, a plurality of cylindrical rollers 16 disposed between the races, and a cage 18 which spaces the individual rollers around the concentric inner and outer races. The outer race 15 has an internal end flange 20, and the inner race 14 has a pair of external end flanges 22 between which a cylindrical raceway surface 24 is formed.

Each bearing roller 16 has a cylindrical surface 26, and opposed, flat end faces 28 which are spaced apart by a distance slightly less than the width of the raceway 24. The intersection of each end face 28 with the cylindrical surface 26 is a smoothly rounded corner 30, as is clearly illustrated in Figure 3. The flanges 22 on the inner race 14 are of a height substantially less than the radius of the cylindrical rollers 16.

Each end flange 20, 22 presents a surface 32 which can engage the adjacent end faces 28 of the rollers 16. The surface 32 is convex, being preferably crowned with a radius of curvature which is relatively large in comparison with the diameter of the rollers 16. Preferably, in the case of a typical size of bearing, in which the rollers 16 are about 0.4 inches in diameter, the surfaces 32 are formed with a radius of curvature of between 3 inches and 20 inches, and most suitably of approximately five inches. The configuration of the surfaces 32 substantially reduces wear on the end faces 28 of the rollers, as described below, owing to the wedge-shaped space 34 established between the upper portion of the surfaces 32 (as seen in Figure 2) and the end face 28.

In operation, the entire bearing assembly is normally arranged in a bath of lubricating fluid. The rollers 16 roll within the raceway 24, with the cage 18 acting to space the individual rollers about the periphery of the co-axial races. Because of

the difference between the width of the raceway 24 and the slightly smaller width of the rollers 16, each roller 16 can assume a slightly skewed disposition, as illustrated in exaggerated form in Figure 4, with the roller disposed at a skew angle "α" relative to the direction of movement illustrated by arrow 36 in Figure 4. The convex curvature of the end flange surface 32 also affects the skewing angle "α".

As a result of this skewing, one or other of the end faces 28 of each roller will contact one of the surfaces 32 at a location 40 which lies ahead of the centre of that roller in the direction of movement of the roller (or, at least, the thinnest part of the lubricant film will occur at the location 40). The convex curvature of the surfaces 32 ensures appropriate lubrication at the location 40. More particularly, the radius of curvature, R_f, of the surface 32 is so chosen that the location 40 is below the outer corner 37 of the end flange surface 32 (as seen in Figure 6) by a distance "X", preferably about one-third of the height of the flange surface 32, and preferably inwardly from the outer rounded corner 30 of the roller at a radius R_c from the roller axis, as is illustrated in Figures 5 and 6. By such appropriate curvature of the surface 32, according to the formulae given below, it is ensured that the wedge shaped area 34 is maintained between the end surface 28 and the convex surface 32:

$$2\,R_f = \frac{[R_o - R_i - X]^2 + [K \tan\alpha - 1/2\,(W_r - W_b)]^2}{K \tan\alpha - 1/2\,(W_r - W_b)}$$

Where:

$$K = \frac{1}{2(R_i+R_r)}\sqrt{[(R_o-X)^2-(R_i+R_r-R_c)^2][(R_i+R_r+R_c)^2-(R_o-X)^2]}.$$

and:

R_f=radius of curvature of surface 32
R_i=radius of curvature of raceway 24
R_o=radius of top of flange 22
R_r=radius of roller 16
R_c=radius to location 40 (from roller axis)
X=distance from top of flange 22 to location 40
α=skew angle
W_b=width of roller 16
W_r=width of raceway 24

The position of the location 40 is such that the instantaneous velocity of the roller end face 28 relative to the convex surface 32 is in the direction illustrated by arrow 38 in Figure 5. Accordingly, the instantaneous relative velocity adjacent the space 34 includes a downward component, and therefore rotation of the roller 16 tends to drag lubricating fluid into the wedge shaped space 34 and towards the location 40, to establish and maintain a hydrodynamic lubricating fluid film between the roller surface 28 and the adjacent convex surface 32 throughout operation of the roller bearing.

For comparison, Figure 7 illustrates a known form of roller bearing. In this bearing, the skewed disposition of a roller 16 will sooner or later cause the roller end face to contact the outer corner 42 of an adjacent end flange on the raceway. This is possible because there is no wedge-shaped space equivalent to the space 34, into which lubricating fluid can be dragged to form a lubricating film. Damaging metal-to-metal contact will therefore occur. While certain previously proposed bearings have attempted to alleviate this problem by providing a slanted contact surface on the end flange similar to the slanted surface 44 on the outer race 15 of Figure 1, this approach still does not solve the end wear problem because the roller, owing to initial manufacturing tolerances and/or subsequent wear, will ultimately contact the outer corner 42 to promote the damaging metal-to-metal contact. Similarly, it is not possible to maintain a wedge-like space above the location of contact with a flat end flange surface by providing a crown on the end surface 28 of the roller 16, because the end flange will not normally extend past the roller axis, and it is only at points on the roller axis or at a similar distance from the raceway that true tangential contact between flange and roller can occur.

Another form of roller bearing is illustrated in Figure 8 to 11. In this arrangement, the roller end surface 46 is crowned rather than flat, as is the face 28 of the first embodiment. A slight crowning of the end face 46 further enhances roller bearing life. In Figure 10, the elliptical area shown at 48 indicates the area over which an

effective lubricating film is formed. As in the previous embodiment, the end flange surface 32 is convexly formed with a radius of curvature selected to produce the desired wedge shaped space 34 above the location 48; the velocity of the cylindrical roller relative to the race at this location causes it to force lubricating fluid inwardly towards the location 48 while rolling upon the inner raceway to produce a hydrodynamic lubricating fluid film between the end face 46 and the adjacent convex surface 32 at the location 48. For comparison, Figure 12 shows a known form of roller bearing in which a convex end surface 46 is provided on the cylindrical roller, but acts against a flat end surface of a raceway flange, resulting in the same deleterious effect as in the bearing of Figure 7. The roller end face will sooner or later engage the outer corner 42 of the raceway in metal-to-metal contact.

WHAT WE CLAIM IS:—

1. A roller bearing comprising inner and outer members each having a circular raceway, and a plurality of bearing rollers arranged between the raceways, at least one of the inner and outer members having at least one circumferential flange beside its raceway, which flange has a convex surface arranged to engage an end face of each bearing roller to restrain the bearing rollers against axial movement, the convex surface of the flange diverging, in the direction towards the part of the flange which lies furthest from the raceway of the said one member, hereinafter referred to as the crest of the flange, from a plane perpendicular to the axis of an adjacent bearing roller, the said divergence extending from the said raceway to the crest of the flange, and the convex surface of the flange and the end faces of the bearing rollers being so shaped that, even with a bearing roller in its most extreme skewed position, the point of closest engagement between the flange and the bearing roller is spaced from the crest of the flange, with that part of the space between the flange and the bearing roller which also lies between the crest of the flange and the said point of closest engagement being wedge-shaped.

2. A bearing as claimed in Claim 1 in which the inner member has two flanges, one on each side of its raceway, and both the flanges have convex surfaces arranged to engage end faces of the bearing rollers.

3. A bearing as claimed in Claim 2 in which the spacing of the flanges of the inner member and the width of each bearing roller are so related that, when the axis of a bearing roller is coplanar with the axis of the inner member, the roller has a freedom of axial movement between the two flanges.

4. A bearing as claimed in Claim 1 or Claim 2 or Claim 3 in which a central part of at least one end face of each bearing roller is substantially flat and perpendicular to the roller axis.

5. A bearing as claimed in Claim 1 or Claim 2 or Claim 3 in which at least one end face of each bearing roller is crowned.

6. A bearing as claimed in any of the preceding claims in which each bearing roller has a cylindrical rolling surface which is connected to at least one of the end faces of the roller by a smoothly rounded corner.

7. A bearing as claimed in any of the preceding claims in which, as seen in longitudinal section, the convex surface of the, or each, flange is part-circular, and the surface of the raceway beside the or each flange is straight, and substantially collinear with the centre of curvature of the adjacent convex flange surface.

8. A bearing as claimed in Claim 7 in which the radius of curvature of the convex surface of the or each flange is between 3 and 20 inches.

9. A bearing as claimed in Claim 8 in which the radius of curvature of the convex surface of the or each flange is approximately 5 inches.

10. A bearing as claimed in any of the preceding claims in which the shapes of the convex surface of the or each flange and of the roller end surfaces are such that, with a bearing roller in its most extreme skewed position, the point of closest engagement between the flange and the roller is spaced from the crest of the flange by approximately one-third of the height of the flange.

11. A bearing as claimed in any of the preceding claims in which the bearing rollers are contained in a cage.

12. A bearing as claimed in any of the preceding claims in which the or each flange does not extend beyond the axes of the bearing rollers.

13. A roller bearing substantially as herein described, with reference to Figure 1 to 6 or Figures 8 to 11 of the accompanying drawings.

14. A roller bearing including a plurality of bearing rollers rolling between inner and outer raceways, with the end faces of the rollers in engagement with a convex flange formed beside one of the raceways, in which bearing the flange diverges, in the

direction away from the said one raceway, from a plane perpendicular to the axis of an adjacent bearing roller, with the said divergence extending along the whole height of the flange, and the points of closest engagement between the flange and the bearing rollers are spaced from the crest of the flange, resulting in a wedge-shaped space being formed between the flange and each bearing roller, along the part of the height of the flange lying between the crest of the flange and the said point of closest engagement, and the bearing being so arranged that, when the inner and outer raceways are rotated relative to one another, the velocity of each bearing roller relative to the flange at the respective said point of closest engagement includes a component directed from crest to base of the flange, which component produces a hydrodynamic lubricant film between the flange and the bearing roller.

15. A roller bearing assembly having an inner race, an outer race, and a plurality of cylindrical rollers each having opposed end faces and a cylindrical surface in rolling engagement with the inner and outer races; a pair of radially extending flanges on one of the races adjacent the opposed end faces of the rollers, the said flanges presenting convexly curved surfaces engageable with the said end faces, which curved surfaces diverge, in the direction away from the part of the said one race which joins the said two flanges, from a plane perpendicular to the axis of an adjacent roller, with the said divergence extending along the whole height of the flange.

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Agents for the Applicants.

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1520060 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

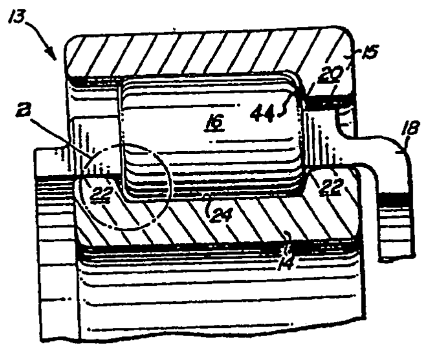


FIG-1

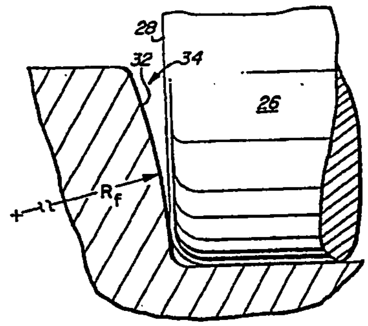


FIG-2

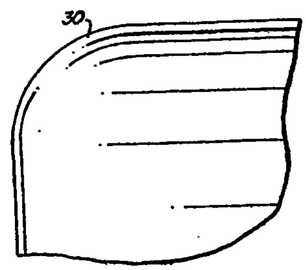


FIG-3

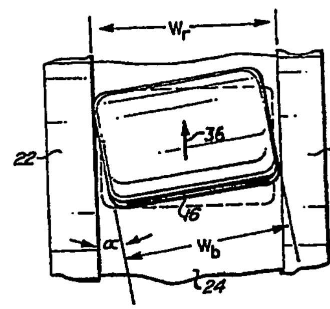


FIG-4

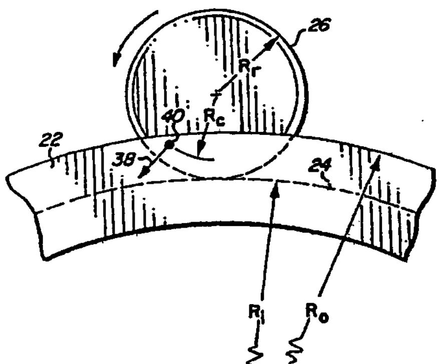


FIG-5

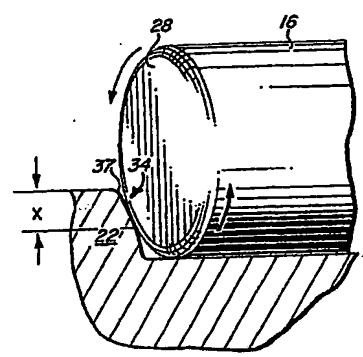


FIG-6

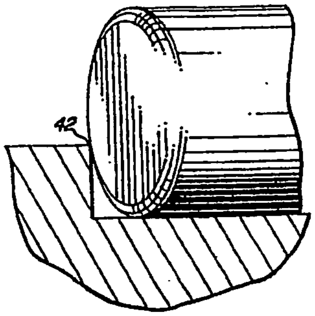


FIG-7
(PRIOR ART)

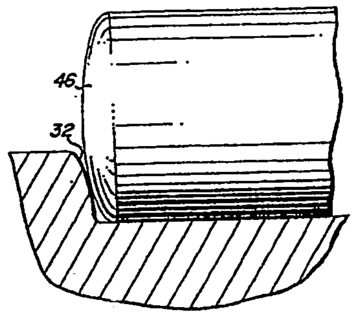


FIG-8

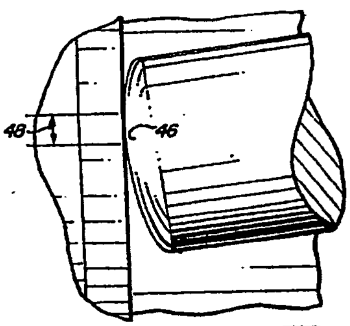


FIG-9

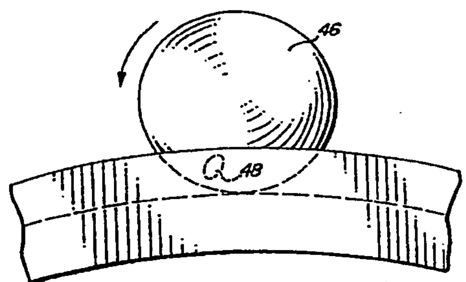


FIG-10

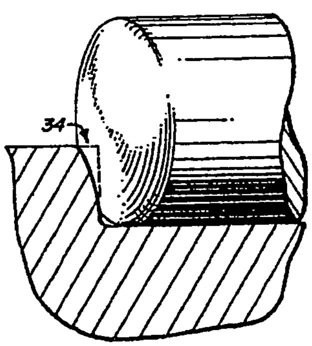
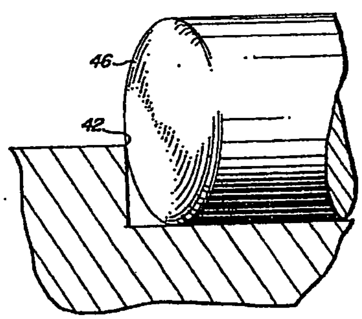


FIG-11



(PRIOR ART)
FIG-12